Philosophical Transactions

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PHILOSOPHICAL TRANSACTIONS.

May 23. 1670.

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The Anſwer

Of Monſieur Mariotte *to Monſieur* Pecquet, *about the Opinion, that the* Choroeides *is the Principal Organ of Sight; communicated to the Publiſher from* Paris, *and Engliſhed as follows.*

SIR,

I Have in your Anſwer * ſeen the reaſons, which hinder you from believing that the *Choroeides* is the Principal Organ of Sight; but though they were very Acute, and carried a great deal of Probability with them, yet I did not find them ſtrong

* *Vid. N°. 35. of theſe Tracts, p. 668, 659, 670, 671.*

enough to oblige me, to grant back again this Preeminence to the *Retina*.

You ſay, in your *firſt* Objection, that if the *Sclerotis* and the *Choroeides* be taken away from an Eye that is very freſh, and that the *Retina* be left diſtended on the Vitreous Humor, one ſhall not be able to ſee well through this membrane: whence you conclude, that it is not tranſparent enough, to let ſo much light, as is ſufficient for viſion paſs upon the *Choroeides*.

In my opinion, there is good reaſon to doubt of this conſequence, ſeeing there may be a great deal of difference between the Retina of a dead Animal, after it hath been expoſed to the Ayre, and that of a living Animal, while it is exactly ſhut up between the Vitreous humour and the *Choroeides*. Different diſpoſitions do ordinarily change the qualities of things; Fat, which is tranſparent when it is melted, grows opacous after it is cold again; and the *Tunica cornea* of an Eye being held ſome hours in ones hand, in a hot Ayre grows thick, and a little after entirely opacous. But to the end you may be perſwaded, that the *Choroeides* is ſufficiently enlightned in a living Animal, you muſt take the Eye of an Ox (newly kill'd) while it is hot, and cut it in two, in ſuch manner that a good part of the vitreous humour may remain extended upon the *Retina*; then you ſhall ſee diſtinctly the colours of the *Choroeides*, the baſis of the Optick nerve, the trunck of the little veſſels which proceed from thence, and their diſperſion through the thickneſs of the Retina, with ſo much perſpicuity that you cannot even diſcern, whether there be a Retina beyond the Vitreous humour or no. Hence you may judge, that the light, which the Objects ſend to the *Choroeides*, is more than ſufficient for viſion, ſeing that being much weakned by the reflexion and by a ſecond paſſage through the Retina and the Vitreous humour, it is yet ſtrong enough to form a clear and diſtinct viſion of the *Choroeides* in our Eyes.

Not that I deny the Retina to have ſome whiteneſs in a living Animal, and that it is a little leſs tranſparent than the other Humours, chiefly in that part which is contiguous to the *Choroeides*; and Nature may have made it ſo on purpoſe to temper the brightneſs of great lights, and to hinder dazeling; in like

like manner as ſhe hath ſpread over our skin an inſenſible *Epidermis*, to keep it from being too eaſily hurt by thoſe bodies that touch us, and by the Exceſs of heat and cold. But if I ſhould abſolutely deny, that the Retina hath any opacity in a living Animal, your Experiment would not convince me, it being made but upon a Retina, whoſe more ſubtle and tranſparent parts are evaporated; and I might propoſe to you for an example a piece of white paper, through which, when it is wet, one ſees diſtinctly enough whatever is contiguous to it; and which preſently reſumes its firſt opacity, when it is a little while expoſed to the Air: And if this Example were not ſufficient, I might alledge the little Chryſtalline, which is found in the middle of the Chryſtalline humour of many Animals, and is as it were the kernel of it; the which, being as tranſparent as the other humours of the Eye in a living Animal, becomes in two or three dayes after his death white and opacous, notwithſtanding that it be left incloſed in the Eye, and that the Exteriour Chryſtalline remain ſtill tranſparent.

Your *ſecond* Experiment to prove the opacity of the Retina, which is to put it into water, is alſo extremely deceitful: For, you make no doubt but the *Hyaloeides*, which invelopes the Vitreous humour, is perfectly tranſparent: nevertheleſs if you lay in a diſh half full of water, part of the Vitreous humour, the parts of the *Hyaloeides*, which ſtick to it, will appear whitiſh and thick like a ſpiders web, although the Vitreous humour do ſtill retain its tranſparency. It is not then a ſufficient proof to know, whether the Retina be opaque in a living Animal, by putting it into the water: And by what tryal ſoever you make of it, after it has been expoſed to the Ayre, you can draw no conſequence to prove that it is opaque in its Natural ſtate: For the Chryſtalline it ſelf becomes a little thickiſh in water, and if it be left there ſome time, or expoſed to the froſt, it becomes white and opaque like ſnow.

It is therefore neceſſary for reſolving our difference, and for knowing with certainty, whether the light of objects paſs almoſt all entire to the *Choroeides*, or whether it is almoſt all intercepted by the *Retina*, to bring obſervations made on the *Retina*

and the *Choroeides*, while they are in their natural ſtate, as I ſhall do in the following Experiment.

Place by night a lighted Candle very near your Eies, andcauſe a dog, diſtant from the candle 8 or 10 paces, to look upon you, then you ſhall ſee in his eyes, a light ſufficiently bright, which I hold to proceed from the reflexion of the light of the Candle, whoſe image is painted on the *Choroeides* of the dog, which having much whiteneſs and luſter cauſes this very ſtrong reflexion; for if it proceeded from the Chryſtalline or Retina, the ſame appearance would be ſeen in the Eyes of Men, Birds, and other animals, who have the *Choroeides* black, which is not found ſo by us. It is therefore manifeſt by this Experiment, that the luminous rayes do paſs with a great deal of force as far as the *Choroeides*, and that the *Retina* receives very little impreſſion. Now this appearance is made in this manner: The little picture of the candle which is upon the *Choroeides* of the dog, (where is the *Focus* of the Chryſtalline and other humours together) ſending rayes back through theſe humours, makes its reciprocal *Focus* towards the candle, and by conſequence the eyes which are near to the point, where theſe rayes do reunite, ought to ſee the Chryſtalline of the dog very much illuminated. They that are skilled in Opticks know the demonſtration: and there is an effect, wholy like unto this, to be ſeen by a very eaſy Experiment.

Place a round Glaſs-bottle, full of very clear water, 8, or 10 paces from a Candle, and put behind the bottle, at near the diſtance of its Semidiameter, a white paper, in ſuch manner that one may ſee the light of the Candle, which hath paſſed thorow the bottle, reunited in a little ſpace upon the Paper; then they, who have their eyes near the Candle, ſhall ſee the bottle full of light, which will diſappear, if you hold the paper either nearer to, or farther from the bottle. And if one hold a ſmall lighted wax-candle in the place of the Paper, and you hold your eye in the place of the former candle, you ſhall ſee the bottle yet more enlightned then it was before: And one may eaſily judge, that the light which appeareth in the dogs eye, proceedeth from a like cauſe. The ſame experiment may be made in the

the eyes of ſeveral other Animals, and particularly of Cats, in whoſe eyes this light appears blewiſh, which ſhews, that it proceedeth from their *Choroeides* which hath much of this Colour; but this Colour, nor any other which may be in the *Choroeides*, brings no confuſion to the Senſe of Seeing, for the Senſes receive no impreſſion from their own Organs.

The reſt of this firſt Objection hath almuſt no other foundation, but an interpretation you give to ſome words of my writing different from my ſenſe; for, when I ſaid, that dark and opaque bodies receive a great deal of impreſſion from the light; I did mean dark and opaque bodies both together; for it had been ſufficient for me to name dark bodies, ſince all dark bodies are opaque; but my thought on this ſubject was, and ſtill is, that tranſparent bodies, as the Ayre, the Water, and the Retina in a living Animal, receive *little* impreſſion from light, and that Opaque bodies receive a *great deal*, but that dark bodies receive more then all other Opaque bodies, and the Air and the Water a little leſs than the Retina.

Nor do I believe, that darkneſs is abſolutely n ceſſary for Viſion, but only for a ſtrong viſion; nor that the picture of objects ought to be expreſſed on the Organ of Viſion; for, it ſufficeth, that the rayes of each point of the Objects be reunited in a diſtinct and ſeparated point, according as they anſwer one another; and you will eaſily agree, that as a Convex glaſs makes the image of the Sun to appear on white paper with a great deal of brightneſs and light, and on black paper very obſcurely; although black paper (which ſoon takes fire) receives a great deal more impreſſion than white: So the rayes of illuminated objects do reunite on a whitiſh *Choroeides*, and expreſs there a viſible picture, and on a dark *Choroeides*, a very obſcure one, and which cannot be ſeen; but then the impreſſion is alſo much ſtronger in the black than in the white: And this is the cauſe, why Men and Birds ſee better and more diſtinctly then the greateſt part of other Animals; for their *Choroeides* being black, nd by conſequence very ſenſible of light, they contract much their pupilla or ſight-hole of the Eye, which makes the Rayes, that paſs there from each point of the Object, to be all very near the

Axis of the Chryſtallin, and to reunite more exactly in a point, then in the Eyes of moſt other Animals, which have their *Choroeides* white towards the *Axis* of Sight, and by conſequence leſs ſenſible of light, who in recompence can very much dilate the Pupilla of their Eyes, when they ſtand in need of a great light; but alſo their Sight is not ſo diſtinct, becauſe the Rayes, which fall on the Extremity of the Chryſtalline, do interſect the Axis too near in their refraction.

It is true, that to ſupply in ſome ſort this defect, they have a little Chryſtalline in the middle of the great one, and this little Chryſtalline being of a more ſpiſs conſiſtence then the great one, its refraction is alſo more ſtrong, and makes the rayes, which come from one point in the *Axis* and paſs near the Center of the Chryſtalline to retract more then if there had been but one Chryſtalline. And by this means the greateſt part of the Rayes, which fall upon the Extremity of the great Chryſtalline, do interſect the *Axis*; which cauſes their ſight to be leſs confuſed, although it be never ſo diſtinct as that of Men and Birds, which have but one Chryſtalline. *Fiſhes* have alſo a double Chryſtalline, for otherwiſe their ſight would be more confuſed than that of other Animals who live in the Air, for their Chryſtalline being ſpherical, the rayes cut the *Axis* more unequally than if it were lenticular and its convexities were of a greater ſphere; and it ought neceſſarily to be ſpherical, becauſe the refraction of the Rayes, which paſs from the water into the Chryſtalline, is very ſmall, and would make its *focus* too far diſtant if the Chryſtalline were lenticular.

The difficulty of your *Second* objection proceeds alſo from an Ambiguity of words, and conſiſts in knowing, what we are to ſay it is, that has a great continuity and communication with the Brain. My *Hypotheſis* is, that the Nerves are all coated with the *Pia Mater* (which envelops all the Spinal Marrow) and have with it the ſame continuity of fibers; ſo that if theſe nerves be never ſo little moved, the impreſſion is carried to the Brain by the Continuity of theſe fibers; and whether it be, that the texture is different in Nerves of different ſenſes; or that they contain ſome ſpirituous liquors which determine their ſen-

ſenſations, by ſome differences they have among themſelves; it is certain, that the Nerves of Sight, in what manner ſoever they are moved, repreſent Colours and Lights; thoſe of Hearing, Sounds, and thoſe of the Touch, Paines, &c.

Now the *Choroeides* is an Expanſion and dilatation of the *Pia Mater*, which enveloppes internally the Optique Nerve, and which comes from the tuberoſity of the Spinal Marrow, by a continuity of fibe s; whence it follows, that how little ſoever the *Choroeides* be toucht, the impreſſion may be eaſily communicated to the brain: And to the end, that the ſame thing may be ſaid of the *Retina*, there muſt be a little channel in the Optic nerve, through which the Retina in its proper Subſtance extends it ſelf to this tuberoſity by a continuity of Fibers; which is not ſeen, and you are conſtrained to ſay, that there are little filaments of nerves which come from the interiour of the Optick, and expand themſelves through the Retina, which have this continuity; but if there were theſe filaments, they ſhould ſpread themſelves through the Retina, as from a Center to a Circumference, and ſhould lye cloſer together near the Optick nerve, than a good way farther in the Retina: which nevertheleſs we do not obſerve to be ſo.

Beſides, if you thruſt a pin through the thickneſs of the Retina, you will often meet with filaments; but if you look on them through a Convex glaſs, you will diſcover, that they end in little veſſels of Veins and Arteries, which are in the Retina; and infallibly, if there were any nerves, you might find them in the ſame manner, and they would ſtop the Pin, ſince they are as hard and firm as the little Arteries; and when you ſay, that one may diſtinguiſh theſe filaments in the water, becauſe the reſt of the Retina diſappears, that is repugnant to experience, and to what you have ſaid before, *viz.* that the Retina may be ſeen all white in the water, and without tranſparency; and you ought to ſhew theſe filaments, or elſe we ſhall take them for a thing invented at pleaſure.

You bring after that two Experiments; the *firſt* of which is, that if an aperture be made on the upper part of the Eye, we may diſcover the Picture of the Objects on the anterior ſurface of the *Retina*; but if this aperture be made in the white of the Eye,

Eye, the aqueous humour will run to the *Tunica Cornea*, and make wrinkles, which will hinder the Picture from being diſtinct: Beſides, he that looks in at this aperture, will hinder the Rayes of the Object from paſſing into the Eye, and he ſhall ſee nothing there but his own image. But if you mean, that the *Tunica Cornea* ſhould be wholly taken off, there will not then be diſtance enough between the *Chryſtallin* and the *Retina*, to make the Picture diſtinct. In concluſion, I do not believe this Experiment can be made, much leſs that it is to be diſcerned whether this Picture be formed on the anteriour or poſteriour ſurface of the *Retina*, ſince the thickneſs of it is leſs than half a line, or the 24*th* part of an inch; and there is reaſon to believe, that you have truſted to the report of ſome other concerning this Experiment; or that you have believed the images which appear in the Eyes to be painted on the *Retina*, whereas they proceed from the reflexion made on the exteriour of the *Cornea*.

Your *ſecond* Experiment is true and eaſie to be made, but according to you it were impoſſible; for, ſince you hold, that it is on the anteriour part of the *Retina*, that the Picture is ſeen, and that you have elſewhere ſaid, that one cannot well ſee through this Membrane, it follows, that you cannot ſee this Picture through the thickneſs of the *Retina*; but becauſe I believe, there remains tranſparency enough in that part of the *Retina* which is not expos'd to the Air, I doubt not but the Picture may be ſeen on the poſteriour part of it, after it is become ſufficiently opake, though in a living Animal this Picture paſſeth as far as the *Choroeides*, as it hath been already proved: and if the *Retina* it ſelf were taken away, and there remained only the vitreous humour, you might notwithſtanding ſee the inverted Picture of the Windows toward the bottom of the Eye, if you held it at the farther ſide of the room; in the ſame manner as the Picture is to be ſeen in the *Focus* of the ſpherical Glaſs-bottle fill'd with water, though it ſeem to be on the exteriour ſurface of the Glaſs; and by conſequence this Experiment proves not the opacity of the *Retina*.

In your *third* Objection you quote, what I ſaid, a little otherwiſe than I ſpoke it; for I put in my Writing, that the *Retina* was *about* half a line in thickneſs, and not half a line *preciſely*; which

which ſhew'd, I had not meaſur'd it exactly; but if it were but a quarter of a line or leſs, it ſufficeth that it had enough for the effect I did attribute to it: And for another, I did alſo mention in my Writing, which is, that the Rayes of the ſame luminous point, which do not unite preciſely in the ſame points in the *Axis*, are rectified by the concavity of the *Retina*, thoſe that are fartheſt off the *Axis* more than thoſe which are the neareſt, which is the reaſon they unite better in the ſame point on the *Choroeides*; the which point I hold (with you) to be *Phyſical*, ſince the points objective are ſo too; but I hold it to be leſſer than any that can be perceptible to the ſight; for we diſtinguiſh the different parts of very ſmall objects, as the extremities of the breadth of the little arteries of the *Retina*, which make not an eigth part of its thickneſs; and that which repreſents this ſmall breadth, muſt be 25 or 30 times leſs in the Organ of our ſight, that is to ſay, in the proportion of the diſtance of the Object, to the Centre of the ſight, and of the diſtance of this Centre, to the Organ of viſion; and by conſequence the thickneſs of the *Retina* is not proper for this ſmallneſs.

You ſee, then Sir, that hitherto your objections have been able but very lightly to ſhake my opinion, and that the tranſparency of the Retina is well enough eſtabliſhed: Let us come now to the proof, I make of the *Want of Viſion*, on the Baſis of the Optick Nerve.

It muſt firſt of all be agreed, that in this Experiment, almoſt all men do looſe ſight of an intire circle of white paper, whoſe diameter is about the *9th* or *10th* part of its diſtance from the Eye. Now the viſual Triangle, whoſe Baſis is the Diameter of the Circle, and whoſe top is the Center of viſion, is proportioned to the Triangle, whoſe Baſis is the Diameter of the picture of the Circle on the bottom of the eye, and the top, the ſame center of ſight; the which center being diſtant 6 or 7 lines from the baſis of the optick nerve, whoſe breadth is about ¼ of a line, this baſis alſo will be about the *9th* or *10th* part of its diſtance from the Center of ſight, and by the Principles of Opticks, the Image of the circle of the white paper, falling on the baſis of the optick nerve, will cover it preciſely; and becauſe the Paper then wholly diſappears, it follows, that all the baſis

of the Optick nerve is inſenſible of light; whence I conclude, that the *Choroeides* is the Principal Organ of ſight; and that the *Retina* is not, ſeeing it is placed in that part, and is there apparently diſpoſed in like manner as to the reſt of the bottom of the Eye.

To elude the force of this Argument, you alledge other cauſes of this fault of ſight; the two firſt are almoſt like one another. But it ſeems to me, that you ſuppoſe them without any ground: for, as I ſaid before, there are no ſuch filaments of nerves to be ſeen coming out of the baſis of the optick nerve; beſides, they are not proper for viſion, ſince they would leave in the parts of the Retina too great intervals empty; and its neceſſary, that every point of the Object find a ſenſible point in the Organ of ſight to unite his rayes there; which is found in the *Choroeides*, which is an Expanſion of the ſenſible part of the nerve into a continued membrane. Beſides, the cauſes of the defect of viſion cannot be found in theſe *Hypotheſes*; for in the firſt, what reaſon can be given, that there ſhould be no extremities of nerves oppoſite to the optick nerve. ſince there would need only a ſimple direct continuation of ſome of its fibers unto the Anteriour part of the Retina; and for the ſecond (which is the particular opinion) I ſee not, how the void ſpace in the middle of the inverted Tuft, can comprehend all that extent of the baſis whence it proceeds, and why the filaments begin not to receive the impreſſion of the luminous Rayes, but upon the Extremity of this baſis, ſince the rayes of a luminous point, which unite themſelves in a point at the bottom of the Eye, come from divers points of the Chryſtalline, and ſo, if one part of theſe rayes were oblique, the other ſhould be perpendicular, and if all the Rayes ſhould fall perpendicular on the Organ of ſight, there would be no viſion, ſince there is never but one ſingle Ray of thoſe which unite in a point, that falls perpendicular. But I ſhall not inlarge my ſelf to demonſtrate theſe impoſſibilities, ſince I am perſwaded, that theſe inverted tufts, and theſe filaments of which they are compoſed, are but things without a foundation, and which you would have much a doe to ſhew us.

The other Cauſe which you bring, is the trunk of the veſſels which proceed from the baſis of the nerve. Yet you cannot deny

deny but they are very ſmall, and that it is very hard to diſcern the little holes through which they paſs, when the nerve is cut off above its inſertion into the Eye; and becauſe they often come out of the baſis by two ſeveral little holes, the diameter of each of which does not take up the ſpace of above the eighth part of the diameter of the baſis; it follows, that if the reſt of the nerve were ſenſible of light, we ſhould not looſe ſight of a paper of two inches diameter at moſt, at ten foot diſtance: and ſometimes in fixing one eye on a little piece of Paper, two other, very little ones, ſeparated one from the other, would diſappear; which is contrary to experience: for the default of viſion is continued. Seing than the reaſons which you alledg of this default of ſight are either inſufficient, or want an aſſured foundation, it follows, that that which I propoſe muſt ſtand, at leaſt, in reſpect of any thing you urge againſt it. And to confirme it yet more, I will adde here ſome reaſons and obſervations, which are neither in my letter nor in my writing.

The firſt obſervation which is very common, is that of the Pupilla dilates it ſelf in the ſhade, and contracts it ſelf in a great light, and it is very hard to find the cauſe of this unvoluntary motion, but by the Hypotheſis, that the *Choroeides* is ſenſible of light, for then it is eaſy to conceive that it being hurt by too ſtrong a viſion, it may dilate or contract its fibers, which have one continuity with thoſe of the forepatt of the *uvea*, ſo that it can contract its aperture, and when it is not hurt, relax it again: whereas if the Retina be ſuppoſed to be the Organ of ſight, it will be very difficult to explain how this contraction is made.

The ſecond is that of the glaſs bottle full of water, when a lighted candle is placed near its focus: for it is eaſy to prove that if one hold his hand between the Candle and the bottle, he will feel more heat than if he held it in the reciprocal Focus; that is to ſay, the place where the Rayes, which have paſſed thorough the bottle, make a great image of the flame of the Candle appear inverted upon a white ſurface oppoſed to it: for I draw this conſequence, that the Image of a Candle, which is painted on the *Choroeides* of a dog, as I have prov'd to you, makes a much greater impreſſion on the Retina of the dog, than on that of him that lookes on it and ſees it very bright; whence I

conclude that if the Retina were the Organ of ſight, this dog would not ſee the objects indifferently inlightned, which are about the candle, although at 3 or 4 foot diſtance, becauſe they would receive a great deal more impreſſion from this reflexion, and that a great ſenſation doth obliterate a leſſer; which is contrary to experience, and it is not at all likely, there ſhould be ſuch a defect in the ſight of Animals.

The third is, that the Eyes of *Birds* are ſo framed, that the Optique nerve after its inſertion into the Eye is inflected, and extends it ſelf on the Concavity of the *Sclerotis* about the breadth of 2 or 3 lines more or leſs according to the bigneſs of the Eyes; and the length of this inflection is covered by the *Choroeides*, leaving but one little white ſtreak in the middle, from whence the *Retina* takes its Original, which extends it ſelf on the *Choroeides* through all the bottom of the Eye, but it is covered on the ſide of this white ſtreak with a little black membrane as long as the inflexion of the nerve, and almoſt as broad; which proceeds from the *pia mater*, and is as it were an appendix of the *Choroeides*: and if you conſider the ſituation of this membrane, you will find it is near the Axis of ſight, and that the rayes of the Objects, which the Birds look on with both Eyes, fall preciſely upon it after their refraction. Since then in the place, where Viſion ought to be ſtrongeſt, the *Retina* is covered, and that no man doubts but Birds are more clear-ſighted than other Animals; you ought to acknowledge, that the *Retina* is not the principal Organ of Viſion, but that that preeminence belongs to the *Choroeides*.

AN ACCOMPT

Given by Doctor Edward Brown, *concerning the Copper-mine at* Herrn-ground *in Hungary.*

HErrn-ground is a little town, ſeated very high between two Hills, upon a part of land of the ſame name, an Hungarian mile diſtant from *Newſol*. In this town is the entrance into a large Copper-mine, very much digged.

I went in through a *Cuniculus*, called *Tach-ſtoln*, and continued divers hours in the Mine, and viſited many of the moſt remarkable